CHARGE TRAPPING EFFECTS IN THIN FILMS OF Al_2O_3 AND SiO_2

Eliyahou Harari

A DISSERTATION

PRESENTED TO THE

FACULTY OF PRINCETON UNIVERSITY

IN CANDIDACY FOR THE DEGREE

OF DOCTOR OF PHILOSOPHY

RECOMMENDED FOR ACCEPTANCE BY THE

DEPARTMENT OF

AEROSPACE AND MECHANICAL SCIENCES

August 1973

Abstract

Electron and hole traps in MIS devices with pyrohydrolytic Al_2O_3 gate insulator have been investigated, using the MIS device as an integral detector of the charge stored in the oxide. Five electron and four hole trap levels were discovered in the oxide forbidden gap. Their relative densities, spatial distributions in the oxide, capture cross sections and recombination rates have been investigated and are shown to control the device behaviour under ionizing radiation. With a positive gate bias the device radiation hardness is seen to arise from enhanced injection of electrons from the silicon conduction band followed by recombination with excess holes trapped in the oxide.

The same detection technique has been used to investigate ionizing radiation-induced charge trapping effects in thin films of SiO_2 incorporated into MIS capacitor structures. For irradiation at room temperature it appears that holes are lattice trapped at immobile sites with energy at the upper edge of the valence band. Irradiation at 80°K considerably enhances the accumulation of positive charge in the oxide and this is tentatively attributed to holes trapped in the oxide forbidden gap very close to the silicon-oxide interface. Implantation of the thermal oxide with Al^+ and Na^+ ions is shown to considerably increase the density of electron traps in the oxide forbidden gap even after apparently annealing the displacement damage. Preliminary experiments indicate that this by itself does not account for the observed radiation hardening of MIS devices with ion

implanted oxides, and it is suggested that a more fundamental mechanism occurs by which the extensive displacement damage significantly alters the oxide valence band structure and thus changes the mobility of holes generated in the oxide by the ionizing radiation.